CEMENT AND LIME MANUFACTURE

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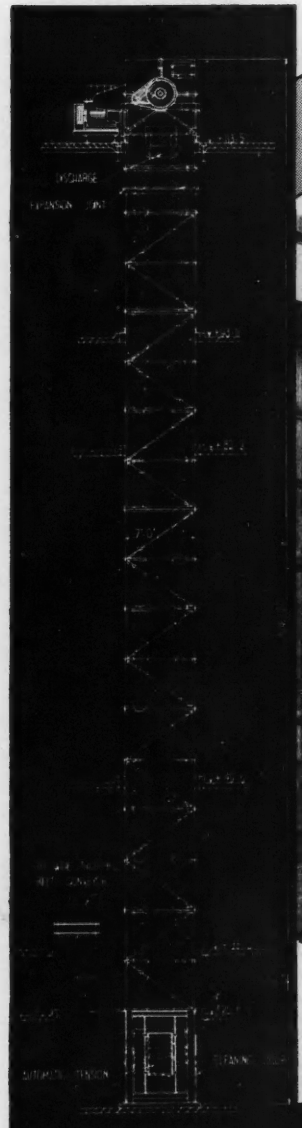

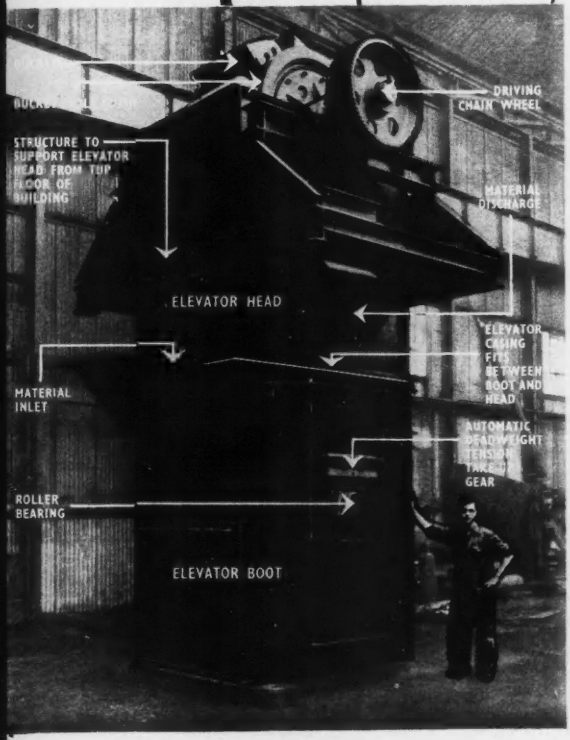

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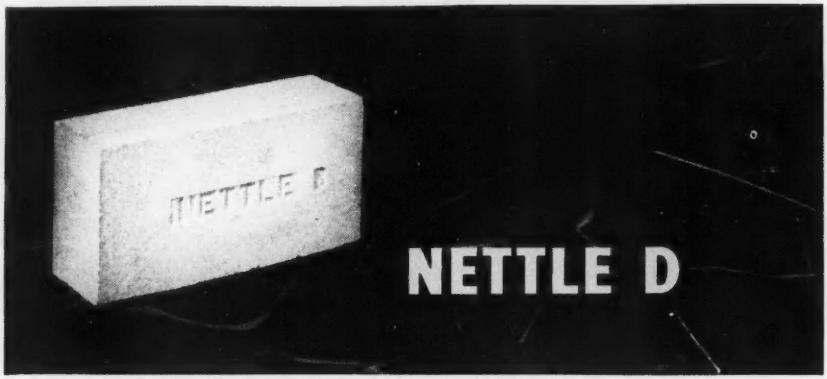

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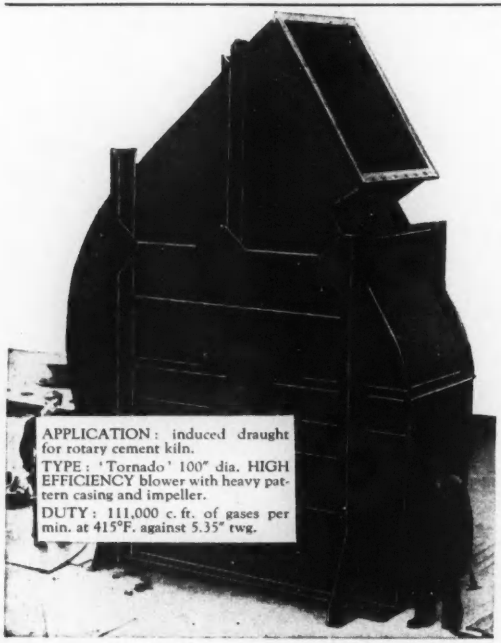

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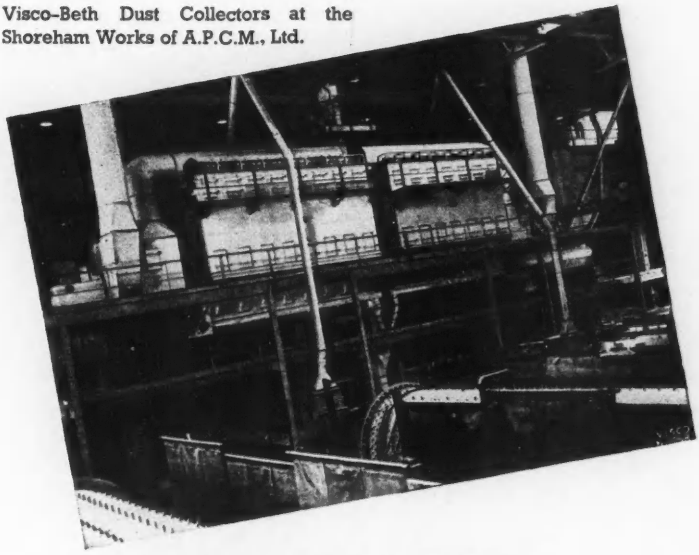

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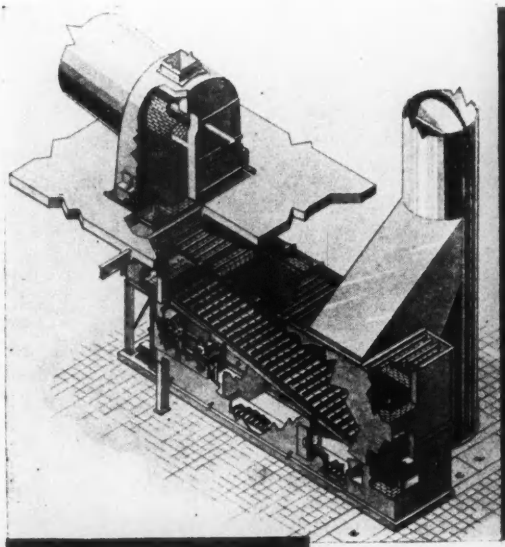

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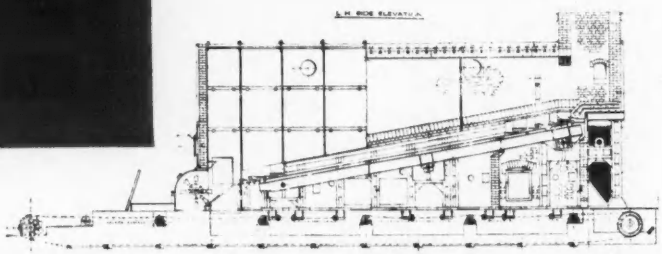

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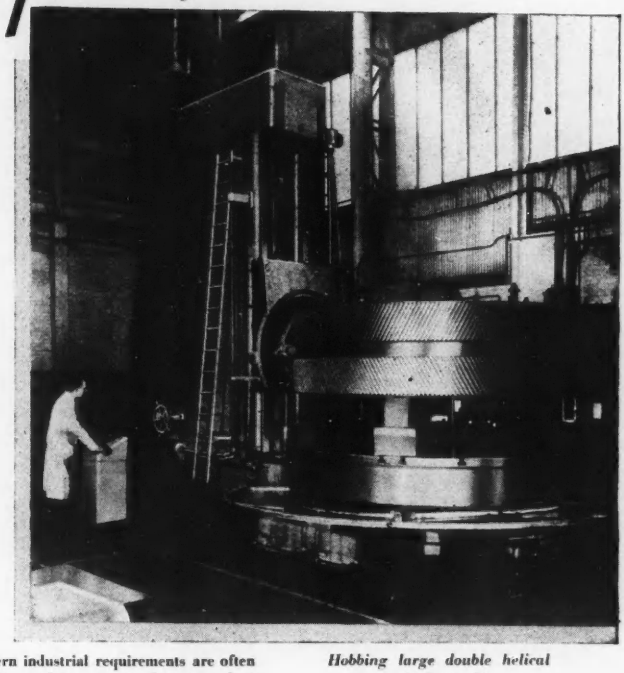

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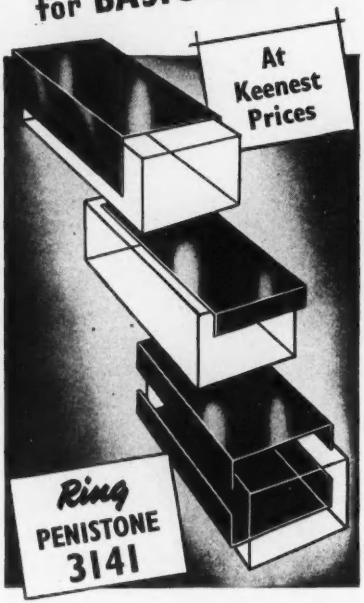

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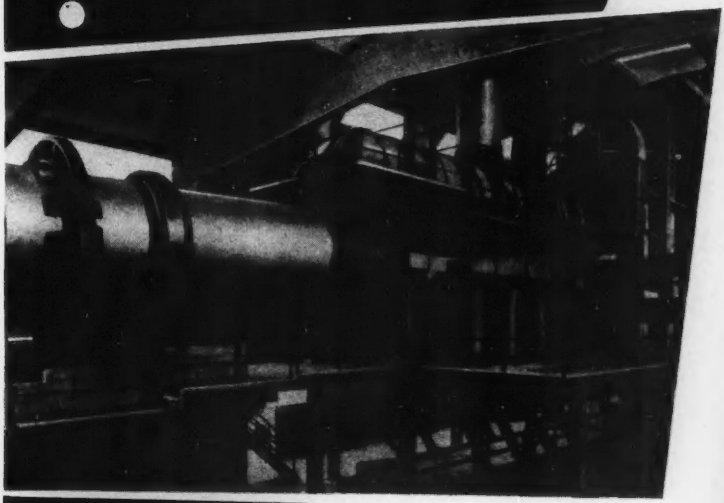

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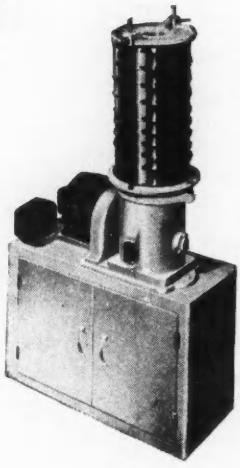

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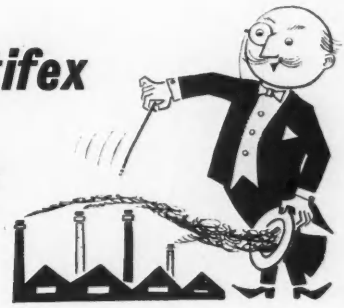

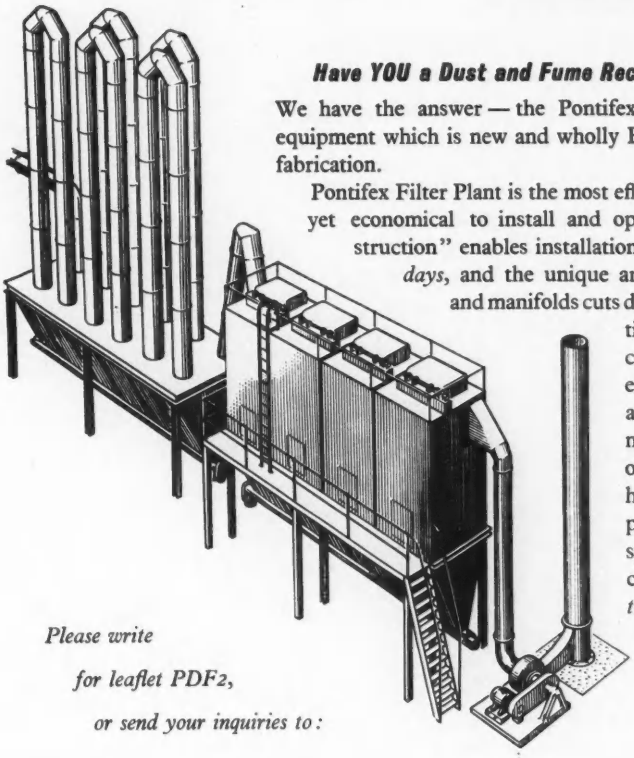

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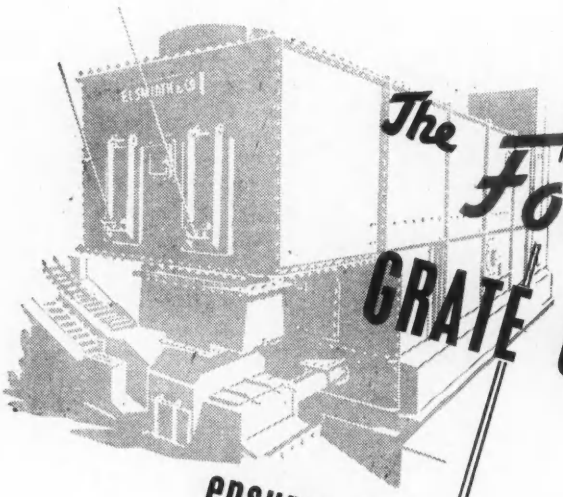

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Reducing the Temperature of Cement during Grinding.

IN a paper presented to the Technical Committee of the American Portland Cement Association, Mr. C. F. Clausen, Director of the Manufacturing Process Department of the Association, suggests that the heat imparted to cement during the grinding process might be reduced if some of the grinding media were removed from the mill and returned after cooling with water.

Fig. 1 is a diagrammatic longitudinal cross section of an apparatus embodying this proposal. The drawing shows an overflow-type single-compartment ball mill or tube mill (1), without a discharge grate for retention of the grinding media, which may be driven through a master gear (2) and a master pinion (3) from a motor (4). The mill is supported on an inlet trunnion (5) and a discharge trunnion (6), both resting in bearings (7). The mill may be equipped with an inlet spout (8) into which is fed the new mill feed (9) from the bottom of a hopper or through a feeder. The mill is charged with grinding media (10) which, during the rotation

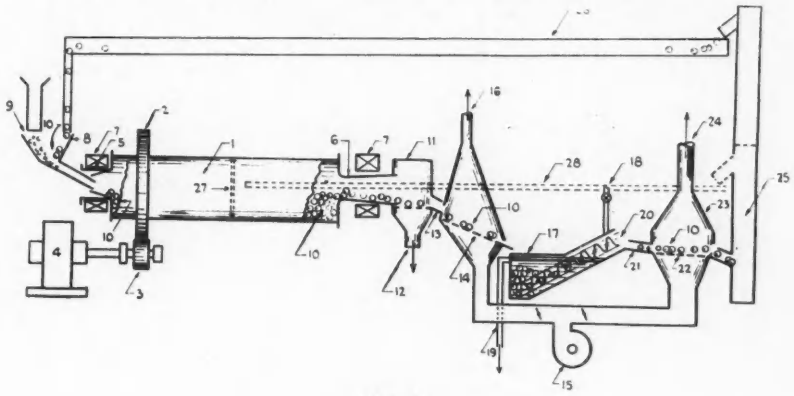


Fig. 1.

of the mill, grind the material to a fineness dependent upon the speed of the mill, the rate of feed, and the weight and shapes of the grinding media.

The ground product and the grinding media are discharged from the mill through the trunnion (6) into a housing (11) equipped with a grate which permits the ground product to be discharged at (12) but retains the grinding media, which flow through a duct (13) on to a vibrating screen (14) through which air is passed from a blower (15). On this vibrating screen any loose product adhering to the grinding media is removed and carried away by the air stream through the duct (16), which may be connected to a dust collector (not shown), while at the same time some cooling of the grinding media takes place.

The cleaned grinding media would then pass from the vibrating screen (14) into the immersion tank (17) equipped with a coolant inlet (18) and an overflow (19), as well as with an inclined conveyor (20), providing a motion of the grinding media in counter-current with the flow of the coolant. The heat contained in the effluent (19) may be used for industrial or heating purposes.

From the inclined conveyor (20) the wet grinding media may pass through a duct (21) on to a screen (22) surrounded by a housing (23) connected to the blower (15). The air stream passing through the grate and leaving the casing at (24) would cause the moisture covering the grinding media to evaporate, thus further cooling the grinding media. The dried and cooled grinding media may then be discharged into a mechanical elevator (25), discharging into a trough or conventional mechanical conveyor (26) through which the grinding media are returned to the feed-spout (8) and enter the mill with the new feed.

A similar arrangement may be used if the mill is operating in closed circuit with a classifier whereby the ground product being discharged at (12) would be elevated to an air-separator from which the tailings may be returned to the feed-spout (8) and enter the mill together with the fresh mill-feed and the returned dried and cooled grinding media. The method may also be used for a multi-compartment mill. The grinding media would then be discharged, as described, with the ground product through the discharge trunnion (6) from the last grinding compartment separated from the rest of the mill by a perforated plate (27); the cooled and dried grinding media discharged from the elevator (25) would then be conveyed through a trough or mechanical conveyor (28) through the discharge trunnion (6) to a point near the feed-end of the last grinding compartment.

In all cases, the total grinding charge of the entire system must consist of the original grinding charge in the mill plus the quantity of grinding media which at any moment is in the discharge housing, on the vibrating screen, in the immersion tank, on the mechanical conveyor, in the drying housing, on the elevator, and in the return conveyor in order to maintain the proper charge in the mill.

EXAMPLE 1.—Using as an example a 7 ft. by 22 ft. single-compartment tube mill charged with 77,000 lb. of grinding balls, driven by a 400-h.p. motor, and having a capacity of 26,300 lb. per hour of material ground from a feed-fineness of 96 per cent. passing a No. 16 mesh sieve to a specific surface of 3230 sq. cm.

per gramme (Blaine), the total energy input per hour would be 400 h.p.-hours= $400 \times 2545 = 1{,}020{,}000$ B.T.U.'s. Assuming that 10 per cent. of this energy is lost in the motor and gears, 10 per cent. is used for size-reduction of the product, 10 per cent. is lost by radiation and convection of heat from the mill, and 70 per cent. is imparted to the ground product as heat, the heat imparted to the product would be $1{,}020{,}000 \times 0{\cdot}70 = 713{,}000$ B.T.U.'s. per hour. If the product being ground has a specific heat of 0·19, the temperature increase in the mill would therefore be $\dfrac{713{,}000}{26{,}300 \times 0{\cdot}19} = 143$ deg. F.

If the temperature of the new feed to the mill is 125 deg. F. and the desired end temperature is 150 deg. F., the temperature increase during grinding should be only 25 deg. F. It will therefore be necessary to remove 82·5 per cent. of the generated heat, that is 590,000 B.T.U.'s. per hour, from the mill. This leaves $713{,}000 - 590{,}000 = 123{,}000$ B.T.U.'s. per hour in the ground product, resulting in an increase of temperature of $\dfrac{123{,}000}{26{,}300 \times 0{\cdot}19} = 25$ deg. F., as desired.

It will thus be necessary to cool x lb. per hour of grinding media (with a specific heat of about 0·12) from a mill exit-temperature of 150 deg. F. (at equilibrium) to an ambient temperature such as 70 deg. F. by means of air, immersion, and evaporation.

$$x = \frac{590{,}000}{80 \times 0{\cdot}12} = 61{,}500 \text{ lb. per hour} = 30{\cdot}7 \text{ tons per hour.}$$

The circulation should therefore be adjusted so as to cool an amount of grinding media equal to about 80 per cent. of the original mill charge from 150 deg. F. to 70 deg. F. every hour in order to produce a ground product that will leave the mill at a maximum temperature of 150 deg. F.

EXAMPLE 2.—A more advantageous example would be a 9 ft. by 15 ft. 6 in. ball mill operating in closed circuit with an air-separator, driven by a 700-h.p. motor, and charged with 120,000 lb. of 5 in. maximum diameter balls of the system having a capacity of 33,800 lb. of ground material per hour reduced from 88 per cent. passing a 2 in. screen to a specific surface of 3300 sq. cm. per gramme (Blaine). The energy input per hour would be 700 h.p.-hours = $700 \times 2545 = 1{,}780{,}000$ B.T.U.'s.

Assuming that of this energy 10 per cent. is lost in the motor and gears, 10 per cent. is used for size-reduction of the product, 30 per cent. is lost as heat through radiation and convection from the mill, the separator and the conveyors, and 50 per cent. leaves the mill as heat in the ground product, the heat in the product would amount to $1{,}780{,}000 \times 0{\cdot}50 = 890{,}000$ B.T.U.'s per hour, and would impart an increase of temperature to the finished product of $\dfrac{890{,}000}{33{,}800 \times 0{\cdot}19} = 138$ deg. F.

If it were desired to restrict the increase of the temperature of the ground

product to 50 deg. F. during grinding, it would be necessary to remove 64 per cent. of the heat, that is 570,000 B.T.U.'s. per hour, from the system. This leaves 890,000−570,000 = 320,000 B.T.U.'s. per hour in the ground product, causing an increase of temperature of $\frac{320{,}000}{33{,}800 \times 0{\cdot}19} = 50$ deg. F., as desired. It would thus be necessary to cool y lb. per hour of grinding media from a mill-exit temperature of 150 deg. F. to 70 deg. F. by air, immersion, and evaporation. $y = \frac{570{,}000}{80 \times 0{\cdot}12} = 59{,}300$ lb. per hour. In this example it would be necessary to cool only 50 per cent. of the original grinding charge in the mill from 150 deg. F to 70 deg. F. every hour, or one 5 in. ball about every second.

The author gives a list of other U.S. patents granted between the years 1921 and 1956 relating to similar means of reducing the amount of heat imparted to cement during the grinding process. [The foregoing is abstracted from "Rock Products" for February 1957.]

Vertical Kilns.

We are informed that the design of the vertical kiln shown in *Fig.* 2 on page 34 of this journal for May 1957 is due to Dr. Steven Gottlieb, of Melbourne, Australia, and not as stated. The design is embodied in British Patent No. 583506 and in many foreign patents, and a kiln of this design was developed under Dr. Gottlieb's supervision in Haifa in 1944.

Controlling the Density of Slurry.

It is reported that the Permanente Cement Co. proposes to install at its works at Cushenbury, California, U.S.A., a density controller which will automatically regulate the consistency of slurry by nuclear means. The device will sense radioactively the density of the slurry below the screen directly through the slurry pipeline by gamma rays and, by automatic impulse, will increase or decrease the quantity of water should it be necessary to vary the density.

Production of Cement in Spain.

Production of cement in Spain in the year 1956 amounted to 3,999,757 tons, an increase of 248,053 tons over 1955. At the end of last year there were 48 factories, with a total annual capacity of 4,757,200 tons, in operation throughout Spain, and seven new plants with a total capacity of 400,000 tons are to come into production during 1957. Authorisation has also been granted for new factories and extensions to existing ones which will increase the national capacity by 1,166,000 tons. Authorisation is pending for other projects which will add a further 935,000 tons per year to the national capacity.

Improving the Flow of Slurry.

IN an article in " Zement-Kalk-Gips " for January, 1957, J. Magasrevy describes the use of calcium lignosulphonate to reduce the water required in the slurry at a works in which closed-circuit grinding and the flotation process are used.

The product from the classifier contains about 80 per cent. of water, and is subjected to flotation before entering a thickener, from which the water that is removed returns to the grinding circuit with the raw material. In this case it is possible to use only a plasticising agent that acts by adsorption, since an alkaline material such as sodium carbonate would accelerate sedimentation.

Anionic flotation with oleic acid is employed, and the solid particles impregnated with oleic acid are strongly hydrophobic. After the thickening process, these particles produce a slurry that can be pumped only if it has a high water content and which very readily separates into coarse and fine fractions. Flow-curves of the non-Newtonian type show that the apparent viscosity of the untreated slurry is increased by small amounts of oleic acid and considerably lowered by calcium lignosulphonate.

Straight-line graphs relating fluidity to water content show that fluidity is considerably improved by calcium lignosulphonate. The effect increases linearly with the amount added up to 0·08 per cent. (calculated on dry solid) for a slurry with 28·5 per cent. of water and a specific surface of 3,800 sq. cm. per gramme. Further additions cause less and less change until with 0·2 per cent. there is no further increase in fluidity. It is clear that the molecules of lignosulphonate are adsorbed on the surface of the particles, since only thus would the reduction in viscosity be maintained after the thickening process. Very little lignosulphonate (200 to 300 milligrammes per litre) remains in the water; this is important since any appreciable amount of lignosulphonate in the recirculated water would interfere with the flotation process.

A quantity of dry ground raw material was treated with a solution of calcium lignosulphonate and the amount adsorbed by the solid particles determined. The concentration of the lignosulphonate was determined colorimetrically by means of the yellow colour produced by concentrated nitric acid. In the case of material with a specific surface of 4,200 sq. cm. per gramme the amount adsorbed increased linearly to 0·08 milligramme per gramme as the concentration increased to 2 grammes per litre, and then a maximum of 0·12 milligramme per gramme was approached with a concentration of 6 grammes per litre. These results correspond with the graphs relating fluidity to concentration. In the case of material with a specific surface of 6,800 sq. cm. per gramme, the amount adsorbed increased in the ratio 6,800/4,200=1·62; this is further confirmation that the phenomenon is adsorption.

The addition of 0·8 kg. of calcium lignosulphonate per metric ton of raw material allowed a reduction in the water content of the final slurry from 36 to 29 per cent. as well as improving its flow properties. The slurry is very stable and requires

only a little air to keep it mixed, and its viscosity does not increase with time. The lower velocity of sedimentation reduces the output of the thickener, but the final volume of sedimentation is reduced by the closer packing of the particles. This decrease in water content increased the capacity of the rotary kiln by 15 per cent. and reduced the heat consumption from 1,625 to 1,400 kcal per kg., and the cost of the addition is relatively small.

No adverse effects on refractory linings or dust emission have been observed during 2½ years. The chain system was modified to suit the change in conditions.

Cement Industry in India.

The Government of India has granted licences for the erection of several more cement works and the extension of two existing works. These are in addition to the licences for new cement works reported in this journal for July and November, 1956, and July, 1957. In the following are given the name of the company to which the licence has been granted, the site of the new works, and the yearly capacity.

Assam Cements, Ltd., of Shillong, Assam—Umtynger (Assam), 66,000 tons.

Associated Cement Co., Ltd., 121 Queen's Road, Bombay—Drug (Madhya Pradesh), 165,000 tons (slag cement 85,000 tons); Veraval (Saurashtra), 165,000 tons.

Standard Mills Co., Ltd., Mafatal House, Backbay Reclamation, Bombay 1—Bhavangar (Saurashtra), 150,000 tons.

Bhagirath Kanoria, General Produce Co., Ltd., India Exchange, 28-29, Royal Exchange Place, Calcutta—Rajur, Madhya Pradesh, 150,000 tons.

Nandlal Kanoria, India Exchange, Calcutta—Chitapur Gulburga District, Mysore, 247,500 tons.

P.A.C. Ramaswami Raja Rama-Maniran, Raja Palaym, Ramnath Puram District, Madras—Ramanataporam, Madras, 16,000 tons.

The extensions are at the government cement works at Churk, U.P. (231,000 tons), and the works at Sindri, Bihar (100,000 tons) of the Associated Cement Co., Ltd.

Lime for Silica Bricks.

The American Society for Testing Materials has produced a tentative standard for lime for use in the manufacture of silica bricks. Among the provisions are the following. Either quicklime or slaked lime may be used, and should have the following chemical composition: calcium oxide, minimum 90 per cent.; magnesium oxide, maximum 2·5 per cent.; combined iron oxide and aluminium oxide, maximum 1·5 per cent.; silica and insoluble matter, maximum 3 per cent.; carbon dioxide, maximum 2·5 per cent. The amount of calcium oxide (or equivalent) shall not exceed 1·5 per cent. susceptible to hydration. Not less than 99 per cent. shall pass a No. 30 U.S. standard sieve, and not less than 95 per cent. shall pass a No. 200 U.S. sieve.

Combined Drying and Grinding of Raw Materials.

THE combination of the drying and grinding processes in the preparation of raw materials in the dry process of manufacture is discussed by Mr. J. R. Tonry (of the American Portland Cement Association) in " Pit and Quarry " for July 1957. The information given, and summarised in the following, is based on practice at nine U.S. cement works.

Typical arrangements for combined drying and grinding are shown in *Fig.* 1. There are three general systems, namely (1) air-swept mill with separator, (2) mill and separator, and (3) air-swept mill with radial classifier. Materials-handling

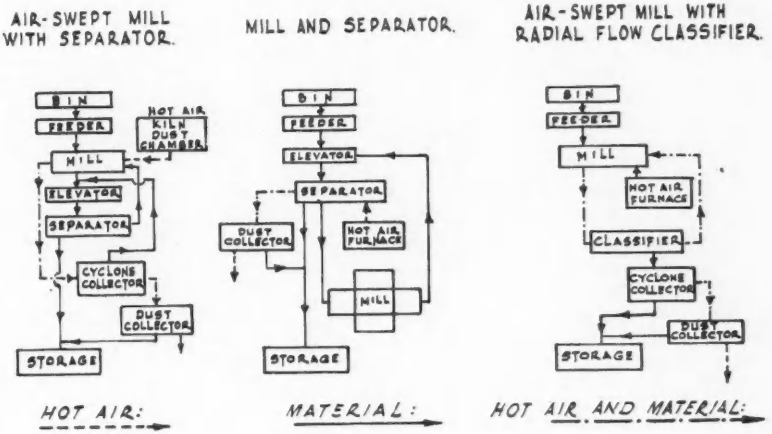


Fig. 1

equipment is not so conspicuous in these systems, and some conveyors are not indicated. *Table* I gives general data relating to the various installations. The main differences, apart from the method of drying, between the separate system and the combined system are larger mills, less handling of materials, and less auxiliary equipment such as dust collectors. The general systems can be divided into two methods of drying, namely by hot air introduced into an air separator, and by a hot-air stream which sweeps through a tube mill. The grinding is by ball mills or ball-and-race mills.

At each works the control point for the regulation of production is an interesting feature. In all cases the classifier is set to produce the desired fineness, and the feed is regulated to a set loading point (the elevator or the classifier) on the mill. Adequate insulation is important in order to avoid condensation of water vapour from the hot drying gases. Materials used for this purpose include rock wool,

Table 1

PLANT INSTALLED	GRINDING MILL	CLASSIFIER SIZE	RATE TONS PER HOUR	FEED		PRODUCT		HORSEPOWER INSTALLED		DUST COLLECTOR			CONTROL POINT	FUEL	RAW MATERIALS
				% MOISTURE	SCREEN SIZE INCHES	FINENESS % PASSING # 200	% MOISTURE	TOTAL	HP. PER TON	TYPE	NO. BAGS MATERIAL	BAG LIFE			
A 1938	Ball & Race	16'	35	1 1/2-3	3/4 Square	90	0.1-0.5	854	24.4	Bag	200 Nylon	?	Elevator Load	No. 4 Oil	Limestone Shale
B 1952	Air-Swept 9'6"x26'	16'	30	1-10	3/4 Slot	94	0.5-0.7	801	26.7	Bag	400 Wool	6 Mo.	Mill Sound	None	Limestone Shale
C 1949	Air-Swept 10'x22'	9'-6" Radial Flow	36	0-1	3/4 Slot	89-90	0.1-0.0	1295	36.0	Bag	390 Nylon	18 Mo.	Mill Power	Coal Stoker	Limestone Shale
D 1954	Ball Mill 10'8"x16'	16'	67	2-3 1/2	5/8 Square	87-88	0.3-0.5	1254	18.8	Bag	408 Cotton	6 Mo.	Elevator Load	Gas or Oil	Limestone Cement Rock Iron Ore
E 1951	Ball Mill 9'6"x15'	16'	36	5-8	3/4 Square	92-94	0.0-1.0	1216	33.8	Bag	546 Cotton	5 Mo.	Separator Load	Gas	Limestone Clay Iron Ore
F 1948	Ball & Race	16'	36	1-5	3/4 Square	92-93	--	754	20.9	Bag	504 Orlon	18 Mo.	Elevator Load	Coal Stoker	Limestone Shale Clay
G 1954	Ball Mill 10'6"x15'	16'	52	3-5	5/8 Slot	89-91	0.2-0.3	1402	27.0	Cyclone Bag	432 Orlon	18 Mo. or more	Mill Sound Device	No. 5 Oil	Cement Rock Limestone Sandstone Iron Slag
H 1951	Ball & Race	16'	36	3-7	1/2 Slot	88-92	0.2-0.8	855	23.7	Cyclone Bag	- 40 Wool felt	3 Mo.	Elevator Load	Coal Stoker	Limestone Clay Iron Ore
I 1905	Roller Mill Tube Mills	16'	116	1 1/2-3	--	88-90	---	3003	25.9	Cyclone Bag	- 216 350 546 Orlon	24 Mo.	Mill Load	Coal Stoker	Limestone Shale

fibre glass, magnesia blocks, and coverings of metal or insulating cement. A feature of these systems is the operation of many units by only two or three men.

Control of production is accomplished in four different ways, namely elevator loading, the sound of the mill, the power requirement, and separator loading. At four works the elevator-loading system, at two the sound of the mill, at one the mill power, and at one the separator loading are used. Any one of four methods may be used to control the operation by the elevator loading. Actual practices are as follows.

ELEVATOR LOADING.—(A) The feeders regulating the raw materials to the mill are equipped with two-speed motors (full speed and half speed). When the elevator motor load deviates from 60 amperes the feeders automatically change speed. For example, if the load is too heavy the feeder automatically works at half speed and after an interval returns to full speed, according to the time cycle. If the system is still overloaded, half speed is repeated, and the timing device repeats its operation. When the load becomes light, the feeders switch automatically to high speed. To get the best results the feeders are set for a load a little greater than is expected, taking advantage of any increase in grindability and keeping the system in a more uniformly-loaded condition.

(B) The operator watches the elevator loading as shown by an ammeter. When the reading passes a marked point, the feed is stopped. If more load is required, a tester from the laboratory adjusts the feeders to provide a greater load.

(C) The operator watches the ammeter on the feed-elevator motor circuit, and keeps the reading between 38 and 40 amps; if the load increases beyond this range, he varies the speed of the stone-feeder belt. The feed of clay and shale is not changed by the operator; this is done by laboratory men. The loading control is closely watched, as an increase in wet material could cause a stoppage.

(D) The miller watches an ammeter on the elevator-drive motor circuit and keeps it between 35 and 38 amps. When it goes outside these limits the feed is varied as required.

MILL SOUND.—(A) The loading is regulated by the sound of the mill and the operator regulates a variable-speed control on the feeders as needed. Consideration is being given to installing a sonic device for automatic control.

(B) Loading is automatically regulated by the sound of the mill. A sonic device is mounted close to the shell of the mill and is protected against dust by a cloth cover. The speed of the feed-belts is regulated to work to a predetermined volume of noise. The critical part of this type of control is establishing the proper sound level to be maintained, and the device must be closely checked.

MILL POWER.—The feed is automatically controlled on the basis of the power consumption of the motor. A recording and indicating controller is mounted on the panel to regulate and keep a continuous record of the operation. Changes of feed are accomplished by varying the speed of the feed-belts or stopping them. The slow speed is two-thirds of the fast speed. A time-delay switch in the circuit prevents too frequent changes in the feed. Actual speeds of the feeder-belt are 30 feet per minute and 20 feet per minute.

SEPARATOR LOADING.—A man controls the feed-belts and watches ammeters on the elevator and air-separator motor circuits. The ammeter reading is kept between 125 and 135 amperes. As a check on the operation, a recording ammeter is connected into the elevator motor circuit.

Dew Point and Insulation.

When wet materials are dried, enough heat must be supplied to ensure that exit-temperatures are above the dew point. Heat losses in uninsulated dust collectors and ducts can cause condensation at normal temperatures, so that adequate insulation is of prime importance. The materials used on all ducts, separators, and dust collectors are as follows: 3-in. asbestos, 2-in. fibre-glass, 1-in. to 2-in. magnesia. For furnace ducts, it is common practice to use 4½-in. refractory and castable linings.

Dust Collectors.

Interesting features of dust collectors are the materials used for the bags, and the double system in which a high percentage of the dust is removed ahead of the cloth collector. At many works cotton, wool, orlon, or nylon fabrics are used for dust-collector bags. Where orlon and nylon are used, the bags have a relatively long life. Where the "scalping" type of collector is used ahead of the cloth collectors, good results are reported. Part of the dust is removed at this point by mechanical collectors, making the work of the bag collectors much lighter. At several works cyclones are used ahead of the dust collectors, and at one works a "scalping" collector plus dual bag-type units is used.

The temperature of the gases entering the dust collector is important if condensation and damage to the bags are to be avoided. General practice is as follows: 150 deg. F., 180 deg. F., 185 deg. F., 170 deg. F., and 180–200 deg. F. ahead of the collector; 180–200 deg. F. on the exit side of the collector.

Grinding Media.

An interesting practice is the screening of samples of the ball charge to determine the sizes needed for replacement. Some examples are as follows.

A mill was first charged with 1-in., 1½-in., and 2½-in. balls and these were changed to improve operation for higher capacity. The mill was first charged with 30 per cent. 2½-in. balls, 30 per cent. 1½-in. balls, and 40 per cent. 1-in. balls —total 67,000 lb. This was changed to 30 per cent. 3-in. balls, 30 per cent. 2½-in. balls, and 40 per cent. 1½-in. balls—total 51,000 lb. To allow for wear, the loading factor is 4 lb. per mill-hour. These balls are added by opening the mill doors. Early in the operation balls of large size only were added, and grinding efficiency was reduced. At another plant the mill is charged with 133,000 lb. of balls and rotates at 119·17 r.p.m. The charge comprises 20,500 lb. of 3-in. balls, 78,500 lb. of 2-in. balls, and 34,000 lb. of 1¼-in. balls—total 133,000 lb. The replacement of balls is 0·111 lb. per ton of material ground. Three-inch balls are replaced in the first compartment and 2-in. balls in the second compartment. Once a month the production is tabulated and balls added as required.

Another mill was first charged with 130,000 lb. of balls, comprising 32,500 lb.

of 3-in., 32,500 lb. of 2½-in., 32,500 lb. of 2-in., and 32,500 lb. of 1½-in. balls. In order to increase production, 25,000 to 30,000 lb. of balls were added. Measurements are made of power input to the mill, and when they consistently show lower results, more balls are added.

At another plant the mill is charged as follows: 15,000 lb. of 2½-in. balls, 30,000 lb. of 2-in. balls, 35,000 lb. of 1½-in. balls, 40,000 lb. of 1¼-in. balls, and 15,000 lb. of 1-in. balls—total 135,000 lb. The replacement necessary due to wear is being studied on small lots of balls removed from the mill. Preliminary studies have established a recharging of sizes as follows per 1,000 barrels (approximately 1,660 tons) of raw material: 3·6 lb. of 2½-in. balls, 6·2 lb. of 2-in. balls, 7·4 lb. of 1½-in. balls, and 10·7 lb. of 1¼-in. balls—total 27·9 lb.

The ball sizes used reflect to some extent the method of preparing feed for the mills. In some plants a slotted-hole screen is used for sizing in order to aid the crushing operation and to permit elongated material to pass to the mills. For example, where a ¾-in. nominal opening is used the product contains particles several times the nominal size in at least one dimension. Where a square hole screen is used closer sizing is obtained and a consistent feed for the mills is prepared. The 3-in. balls used and the nominal feed sizes are as follows: ¾-in. slot, 30 per cent. 3-in.; ¾-in. square, 38 per cent. 3-in.; ⅝-in. square, 25 per cent. 3-in.

A further comparison of ball size, feed size, and production shows the following effect of preparing a smaller feed for the grinding mill: Screen ¾-in. slot: charge of balls 33 per cent., product per ton of balls, 0·54 ton; ⅝-in. slot: charge of balls 37 per cent., product per ton 0·77 ton; ⅝-in. square: charge of balls 40 per cent., product per ton 0·84 ton.

This discussion is to be continued in later numbers of our U.S. contemporary.

New Cement Works in Ghana.

According to Barclays Bank D.C.O., a preliminary agreement has been reached between the Ghana Government and the Tunnel Portland Cement Co., Ltd., of London, to manufacture cement in Ghana. The factory will be at Takoradi and will cost about £700,000. The agreement provides that Ghana will subscribe 25 per cent. of the cost of the plant and the remaining 75 per cent. will be provided by the company. The clinker will be imported from Sweden, Denmark and the United Kingdom. The establishment of this factory follows a government decision not to pursue the exploitation of limestone deposits at Bonyere, in the Eastern Nzima area.

Ghana imported 295,000 tons of cement valued at £2,600,000 in 1955, and 302,000 tons valued at £2,700,000 in 1956. When this project is completed, Ghana will be able to reduce her imports of cement by half.

Effect on Cement of Freezing and Thawing

AT the 51st annual convention of the American Concrete Institute, Mr. F. H. Jackson reported on the results of laboratory tests of cements over a period of fourteen years and of the performance of concrete made with these cements after twelve years' exposure to the weather. This report is particularly concerned with the effect on cement and concrete of exposure to natural freezing and thawing conditions, and is summarised in the following.

(1) Laboratory freezing-and-thawing tests correlate well with the performance of concrete in structures in showing a marked improvement in durability when entrained air is present.

(2) Laboratory tests conducted by the U.S. Bureau of Reclamation indicate a fair correlation between the durability of concrete and the computed C_3A content of non-air-entraining cements, cements with low C_3A content being the more durable. Corresponding tests by the Bureau of Public Roads indicate a similar improvement in the case of cements with a low computed content of C_3S and C_3A, that is Type IV (low-heat) cements. Both these tests seem to correlate fairly well with the performance of a test road at New York where less surface scaling has been observed in sections containing low-heat cements, and test specimens made of lean mixtures with low-heat cements show, in general, less deterioration than comparable specimens made with other cements. Neither laboratory series correlates with the performance of piles exposed to severe conditions in the sea, in which there are only slight indications that durability is affected by the composition of the cement.

(3) There is no correlation between the fineness of cement as measured by the Wagner turbidimeter or the Blaine air-permeability test and the performance of concrete. Cements ranging in fineness (Wagner) from about 1650 sq. cm. per gramme to about 2800 sq. cm. per gramme have been equally satisfactory in all the structures.

(4) Autoclave expansion tests of cements correlate with the performance of concrete to the extent only that low-heat cements have, in general, somewhat less expansion than the other types; however, there were many exceptions.

(5) The various types of mortar-strength tests, as well as the compressive and bending tests of concrete, reveal considerable differences in the strength characteristics of cements that have not yet been reflected in the stability or durability of structures.

(6) Wide differences in the tendencies to premature stiffening or in the "bleeding" characteristics of these cements, although considerably affecting placing and finishing operations, have not so far resulted in corresponding differences in structures.

(7) The results of the autoclave test made on clinkers from which the cements were made show no correlation with performance in structures.

(8) The results of the " sugar " test and the " floc " test do not correlate in any way with performance in structures.

(9) Differences in the drying shrinkage of these cements appear to be without significance from the standpoint of their performance in structures.

It has been shown that, of the many physical tests that were made on the cements under the original programme, only the test for air content is of any value in indicating relative resistance to freezing and thawing. In the case of chemical composition, there is some evidence that non-air-entraining low-heat cements will produce concrete with a somewhat greater resistance to frost than other types of cement. The results of some laboratory freezing-and-thawing tests, as well as the present condition of the New York test road and test specimens stored in the open seem to indicate this. However, there are many inconsistencies not only in the laboratory data but in the outdoor tests as well. For example, in the tests on specimens made with 564 lb. of cement per cubic yard and a slump of 8 in., the specimens containing three Type III (rapid-hardening Portland) cements have all performed as well as the comparable specimens containing low-heat cements, and better in general than the specimens containing Type I (ordinary Portland) or Type II (moderate sulphate resistant) cements. Any conclusion regarding the superiority of low-heat cements would certainly not apply to these specimens. On the other hand, specimens made with 425 lb. of cement per cubic yard containing low-heat cements are generally in much better condition than the specimens made with any of the other cements. No reasoning based on composition alone can be advanced to account for these differences in behaviour, and this raises the question of whether the composition of the cement has any significant effect on the resistance of concrete to freezing and thawing.

It is now generally recognised that damage caused by freezing and thawing is a physical matter. It is known that even well-cured Portland cement pastes with normal water-cement ratios can contain large amounts of water that can be frozen, and that the internal pressures produced by freezing this water may cause damaging stresses. It is also recognised that the resistance of the paste to freezing and thawing depends entirely upon its physical characteristics, that is its porosity, permeability, capacity for freezable water, strength, and elasticity. Consequently the composition of cement can have a significant influence upon the resistance of the paste to freezing and thawing only in so far as it may have a significant influence upon some or all of these physical properties.

During the early stages of hydration, pastes made with cements of different compositions differ in physical characteristics. Cements of some compositions, such as Type III (rapid-hardening), react much faster than others such as Type IV (low-heat). Consequently, if the structures of pastes made with various cements are compared after short curing periods, significant differences will be found. With longer curing, these differences tend to become much less. Although it would be incorrect to say that there are no final differences in the structure of the paste due to the composition of the cement, it is nevertheless true that such

differences as have been found to exist are relatively small in comparison with the very great similarities. Thus all thoroughly cured pastes having about the same water-cement ratio have relatively low permeability and nearly the same high porosity and capacity for freezable water, and roughly the same strength. Therefore, thoroughly cured pastes made with cements of different compositions should not be expected to have greatly different inherent resistances to freezing and thawing. Indeed, it can be said that none of them is inherently resistant to freezing and thawing.

Laboratory tests on air-free pastes have shown that they have little durability Laboratory freezing-and-thawing tests of non-air-entrained concretes made with cements of various compositions have also shown relatively low resistance, although specimens made with different cements may disintegrate at different rates. However, the order of failure in one series of tests may be quite different from that in another series in which a different curing procedure is used. Probably all such results have also been influenced by the small and variable, but important, amounts of air which are present in nearly all concrete, even in the absence of an air-entraining agent.

The degree of damage to well-cured cement paste produced by freezing and thawing is largely determined by the amount of water which freezes in the paste and the number of air voids per unit volume of paste. It is known that the amount of water that freezes cannot be solely or even largely controlled by the composition of the cement, which has no effect on the number of air voids present, as this can be controlled independently. It follows that the behaviour of concrete subjected to freezing and thawing cannot be adequately expressed or understood in terms of the composition of the cement.

For many years engineers have been concerned about the effect of the composition of cement on the resistance of concrete to frost. These studies have afforded the only opportunity to compare the resistance to frost of concrete made with cements of widely different compositions. The results of these observations, as interpreted in the light of other studies, both in the laboratory and in structures, lead definitely to the conclusion that the inherently low resistance to frost of non-air-entrained Portland cement paste is not significantly altered by changing the chemical composition of the cement.

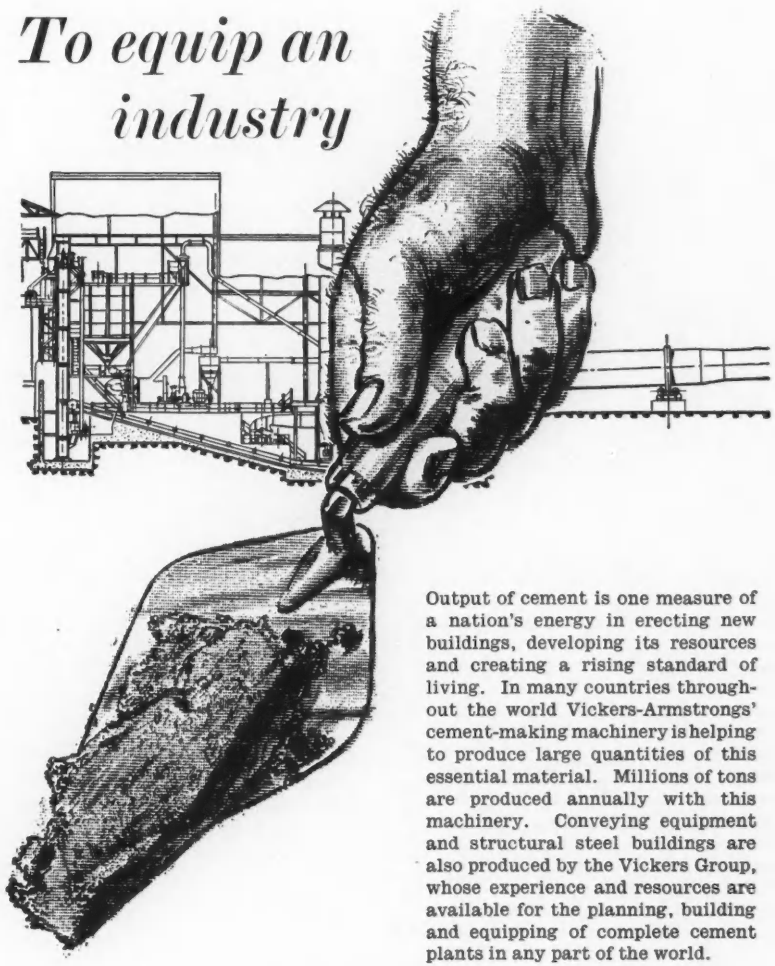
Works Extension in Jamaica.

It is reported that a new mill is being installed at the works of the Caribbean Cement Company; the company aims at a capacity of 300,000 tons a year.

New Cement Works in Honduras

It is reported that a contract has been awarded to a United States firm for the construction of a cement works in Honduras.

To equip an industry



Output of cement is one measure of a nation's energy in erecting new buildings, developing its resources and creating a rising standard of living. In many countries throughout the world Vickers-Armstrongs' cement-making machinery is helping to produce large quantities of this essential material. Millions of tons are produced annually with this machinery. Conveying equipment and structural steel buildings are also produced by the Vickers Group, whose experience and resources are available for the planning, building and equipping of complete cement plants in any part of the world.

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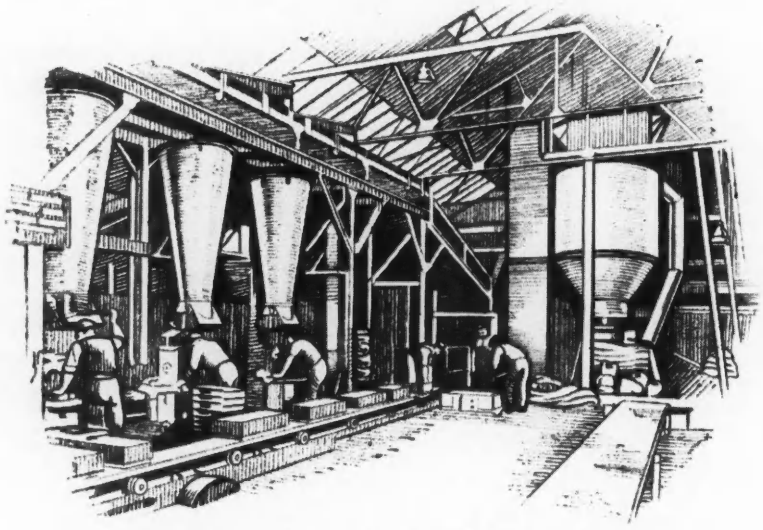

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The Reaction of High-alumina Cement with Water.

A paper entitled " Hydration of Aluminous Cements and its Relation to the Phase Equilibria in the System Lime-Alumina-Water," by Mr. Lansing S. Wells and Mr. Elmer T. Carlson, is given in the " Journal of Research " of the U.S. National Bureau of Standards for December, 1956. The paper discusses at length the work done on this subject by other investigators, and is summarised by the authors as follows.

A study was made of the reaction of water at room temperature with eight high-alumina cements of different compositions. The results were compared with data previously obtained from similar tests on the calcium aluminates. Despite the wide variation in composition, as calculated by the method of Parker, the cements were remarkably similar in their reaction with water. Like the three calcium aluminates less basic than $3CaO \cdot Al_2O_3$, the high-alumina cements produced supersaturated calcium aluminate solutions in which the molar ratio of CaO to Al_2O_3 was slightly greater than 1 to 1. The metastable solutions, originating from the pure calcium aluminates, decreased in concentration rather rapidly as solid phases precipitated out, until a " steady state " was reached at a concentration of about 0·16 gr. of Al_2O_3 and 0·46 gr. of CaO per litre. Solutions from the high-alumina cements similarly reached an average concentration of 0·19 gr. of Al_2O_3 and 0·46 gr. of CaO per litre. In both cases the precipitate consisted chiefly of a hexagonal calcium aluminate hydrate, $2CaO \cdot Al_2O_3 \cdot 8H_2O$, and an apparently amorphous form of hydrated alumina designated $Al_2O_3 \cdot aq$. Small amounts of the isometric hydrate, $3CaO \cdot Al_2O_3 \cdot 6H_2O$, were also found in some instances. The precipitation process was accompanied by an increase in pH from about 11·25 to about 11·7, even though the total CaO in solution was decreasing. This is in agreement with the results given in an earlier paper, in which it was shown that the alumina exists in solution as monocalcium aluminate and that only the CaO in excess of that combined as monocalcium aluminate is effective in raising the pH.

Calculations based on the assumption that monobasic aluminic acid has an ionisation constant of 10^{-10} lead to a theoretical value of about 11·25 for the pH of the hydrolysed calcium aluminate solution, which is in agreement with the average of the observed values for the solutions obtained in the early stages of the reaction of water with the calcium aluminates and high-alumina cements.

The phase equilibrium diagram for the system $CaO\text{-}Al_2O_3\text{-}H_2O$ at 21 deg. C. indicates three stable phases: Gibbsite ($Al_2O_3 \cdot 3H_2O$), $3CaO \cdot Al_2O_3 \cdot 6H_2O$, and $Ca(OH)_2$. The invariant point between Gibbsite and $3CaO \cdot Al_2O_3 \cdot 6H_2O$ is placed at 0·33 gr. of CaO and 0·02 gr. of Al_2O_3 per litre. Metastable solubility curves are given for $2CaO \cdot Al_2O_3 \cdot 8H_2O$, $4CaO \cdot Al_2O_3 \cdot 13H_2O$, and a microcrystalline form of hydrated alumina designated $Al_2O_3 \cdot aq$. This form of alumina separates from the supersaturated solutions as flakes and minute pellets containing 3 to 4 molecules of H_2O per molecule of Al_2O_3. The index of refraction, originally about 1·5, slowly

increases to as high as 1·56, the increase being more rapid at the surface than in the interior of the particles. This study, coupled with the results of X-ray examination by other investigators, leads to the conclusion that the Al_2O_3·aq is Gibbsite in microcrystalline form. Because of its extreme fineness it has a higher solubility than macrocrystalline Gibbsite.

The hydration of the less basic calcium aluminates and the high-alumina cements occurs in the part of the system CaO-Al_2O_3-H_2O in which $2CaO·Al_2O_3·8H_2O$ and Al_2O_3·aq are precipitated. Both are capable of being transformed to more stable phases; the former to isometric $3CaO·Al_2O_3·6H_2O$ plus alumina, the latter to macrocrystalline Gibbsite. The region of formation of $4CaO·Al_2O_3·13H_2O$ is not reached in these hydration processes. The part played by monocalcium aluminate hydrate is still largely undetermined.

Higher temperatures accelerate the transformation of the metastable to the stable solid phases. The rapid conversion of the hexagonal hydrated aluminates to the rounded grains of $3CaO·Al_2O·6H_2O$ is usually considered to be the chief cause of the retrogression in strength undergone by high-alumina cements on heating. It is here suggested that the ageing of Al_2O_3·aq to macrocrystalline Gibbsite may be an important factor in the loss of strength at higher temperatures. Experiments with hardened pastes of three high-alumina cements indicated that monocalcium aluminate hydrate is the chief hydration product at 24 deg. C., while tricalcium aluminate hexahydrate predominates at 80 deg. C., and a number of other phases are formed at intermediate temperatures. The surface areas of the pastes cured at 24 deg. C. were much higher than those of pastes cured at higher temperatures.

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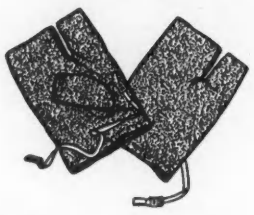

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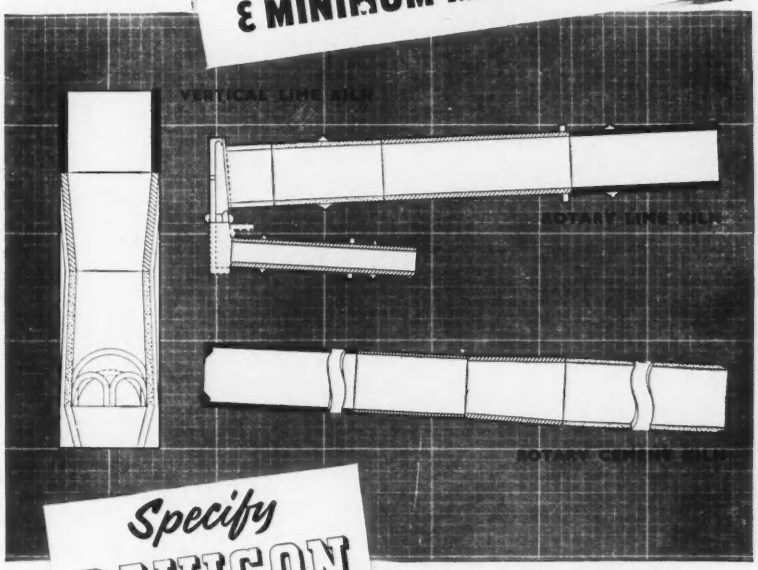

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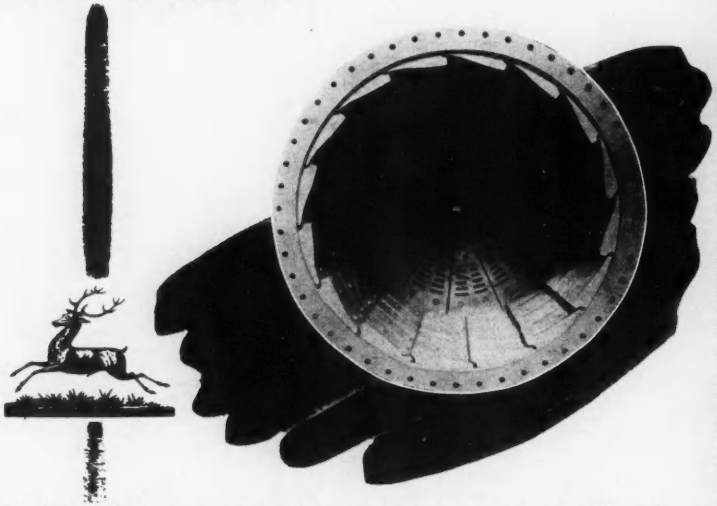

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